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THE USE OF VARIOUS SCHEMAS TO ASSIST SCIENCE TEACHING AND LEARNING.

UTILIZACIÓN DE ESQUEMAS DE DIFERENTES TIPOS EN LA EDUCACIÓN EN CIENCIAS

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Abstract

This paper reports the use of different types of schemas to teach and to learn Science subjects. The schemas used for that purpose can be classified into three types. The first type - curricula schemas, help to combine concepts of the course program into system. A second type - schemas of educational contents, reflect the concrete educational contents of the program, which can contain supporting signals of Shatalov. The third type algorithmic- schemas are used for help in solving problems and carrying out different kind of exercises and laboratory works. Schematic representation of teaching information allows the teacher to present the didactic materials in a more effective way and helps students to learn science theories and concepts more meaningfully.

Keywords: Schemas, science , teaching, learning

Resumen

Se analiza la utilización de los esquemas de varios tipos para la enseñanza y aprendizaje de las ciencias. Estos esquemas se pueden clasificar en 3 tipos: A) esquemas de programa, los cuales representan el sistema de los conceptos claves del curso o del tema; B) esquemas del contenido docente, los cueles se utilizan para representar el contenido concreto del programa y pueden contener los señales de soporte de Shatalov; C) esquemas de algoritmos, útiles como ayudas para cumplir las tareas en laboratorio y rersolver los problemas. Esquemas de estos tipos, ayudan al profesor a presentar más adecuadamente el material de los estrudios en modo visual y ayudan también al estudiante a aprender el material teórico-

práctico con mayor calidad de conocimientos.

Palabras clave: esquemas, enseñanza, aprendizaje, ciencias

Abbreviations used in this text:

ISW - independent students'work

CSs - curricula schemas

CMs - concepts maps

SECs - schemas of educational contents

ASs - Algorithmic schemas

SSs - supporting signals

INTRODUCTION

Many of the common problems students have in studying different courses of Science are based on naive understanding and rote learning of its concepts and laws. We believe that teachers and authors of textbooks do not always present the didactic materials in a suitable way to help students learn science subjects effectively. Similarly, information in many textbooks is not presented in ways most helpful to the learner.

Recently, many teachers have begun using the different kinds of schemas for a better presentation of information taught in classes and for the organisation of independent students' work (ISW) 1 . In this article we will explore the experience of using this effective tool in science education. Our analysis will be made on the basis of published articles in western literature and information from a former USSR sources. It is of of interest because the soviet educational experience is not well known by many teachers and researchers in the West.

The schematic representation of educational information of any subject is mainly based on three didactic principles: (a) a system approach, (b) structuring, and (c) the use of visual methods. This topic has been developed in the books and articles of Bruner J., Ausubel D., Novak J., Shatalov V., and other researchers. All of the knowledge in the field of science subjects should constitute a meaningful and self-consistent system. There are links among distinct elements of knowledge, and this system provides for the transfer of knowledge acquired to **new** conditions. For example in Chemistry courses , students are to be able to substantiate their statements about substances and processes and to use this knowledge in practical contexts such as solving problems and work in the laboratory. More meaningful learning can be achieved by a careful arrangement of the material and by organising the process of instruction on the basis of compactness and continuity of work. Thus a special structure of didactic material is created in which the representation of material is characterised by logic and succession as well as by compactness. So schemas can play a vital role compared with other traditional instructional tools.

There are some works on the theoretical basis for the necessity of using schemas in education. For example, Bruner's classic work (Bruner, 1960) deals with the importance of the structure of knowledge for forming a better understanding of the subject. The older schema theory of F.Bartlett, who defined a schema as an active organisation of previous reactions (responses) and previous experience (Bartlett, 1932; Caremelli, 1986) and its modem application (Anderson & Pearson, 1984) are both important in this area.

Visual aids play a very significant part in the teaching of many subjects. All science teachers use many visual aids to demonstrate links between concepts and for a more compact presentation. Some teachers consider these aids vitally necessary for the mastering of new material irrespective of the students' ages and individual abilities. It should be pointed out that visual representation here is not simply an auxiliary teaching tool illustrating knowledge, but is an essential aspect of cognition and reasoning processes. A human is known to receive 90% of his knowledge through visual signals. Visual aids increase the perception of knowledge, consolidation of material, and knowledge quality. (Orlik 1988) The effective use of visual aids increases the portion of information mastered actively in the memory (Antonov, 1988; Bespalko, 1988).

The schemas used for presentation of educational material in science can be classified into three types (Orlik 1988) (Fig. I a). The first type

A

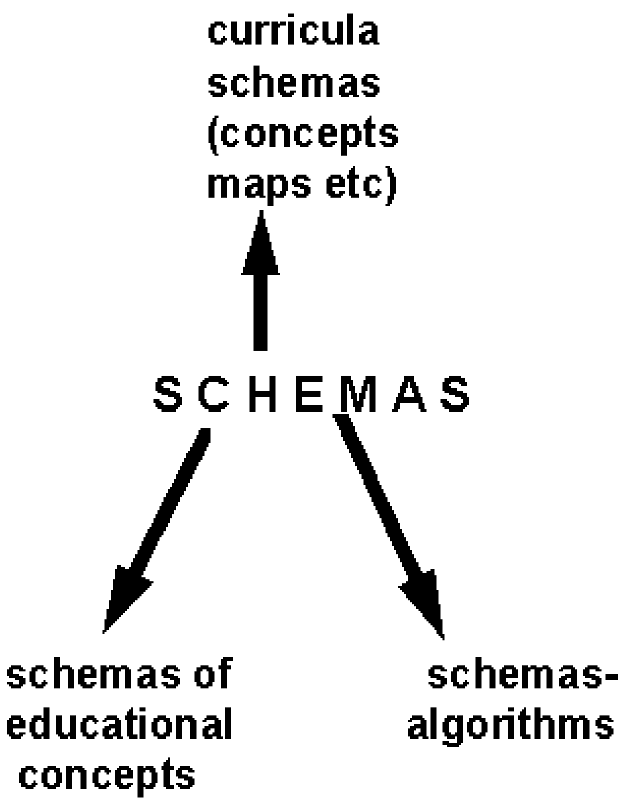
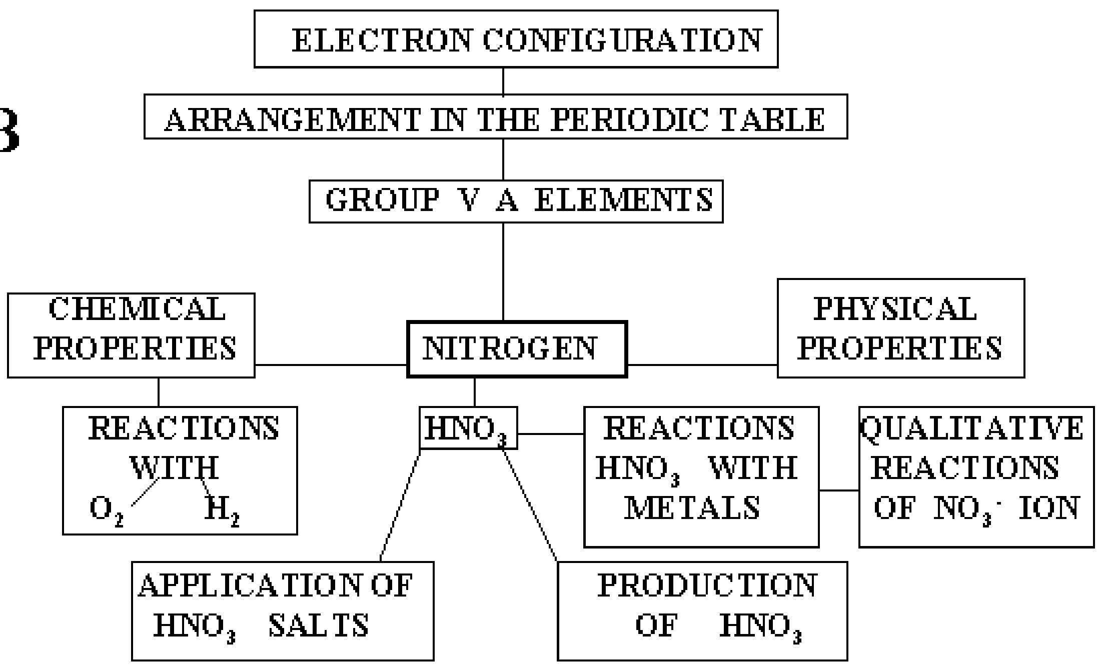


Fig. 1. A. Types of schemas used in Education;
B. Example of CSs from an Inorganic Chemistry course

B



(a) the curricula schemas (CSs) , combine concepts into systematic theoretical course programs. In western literature many of these schemas are named "concept maps" (J.Novak) . A second type - (b) the schemas of educational contents (SECs), reflect the concrete educational contents of the program (summary-schemes, schemes of supporting signals of V.Shatalov, etc.). The third type - algorithmic-schemas (ASs) are used to help in solving problems, carrying out different kind of exercises and so on. It is interesting to characterise these three types of schemas in more detail.

Curricula schemes (CSs)

The main part of these types of schemas are concept maps (CMs). J.Novak's approach in concept map construction is the most well-known in western pedagogics. CMs aim to represent significant relations between the concepts in the form of propositions (Novak & Gowin, 1984). At the same time they play a vital role in representing the general structure of knowledge and illustrating changes or lack of changes in a student's conceptual understanding (Novak, 1977; Pendley, Breth & Novak, 1994). Some CSs are associated with the so-called speciality schemas applied in curriculum design and planning by departments and faculties. For example, a CS introduced for the course of General Chemistry (Zaitsev, 1983) can be considered as a means of information conversion integrating large parts of a theoretical course without overwhelming the reader with detail. In the above example the author used generalised Css for effective chemical curriculum building.

CSs can be constructed using modelling and information methods based on the theory of graphs and matrices (Bespalko, 1989). These schemes enable, the students to comprehend the material and the underlying causal links between parts and topics of a given course. These schemes **visually** demonstrate the system of course themes, the inner structure of the material and, if necessary, interdisciplinary links. These are quite vivid. In Fig. 1B is an example of a CS for part of an Inorganic Chemistry course (Orlik & Mozolevskaya, 1990).

Structuring the content of curricula in the form of CSs (or CMs) is more often carried out for relatively small parts (topic section) of the theoretical course. In this example (Orlik & Mozolevskaya 1990) we structured the whole course around CSs. As a result, we have a set of CSs for various parts and topics which form the network of contents and graphic links. Such global schemes of the whole course, as depicted in the plan, appear to be rather difficult for a student at first glance. They are mainly of interest for teachers and researchers who can use it for planning and arranging the material of the whole course. It has been demonstrated that such schemas help to avoid unnecessary repetition of didactic material and to make the curriculum more effective (Orlik, 1988).

The global CS of the whole course can help us to understand more clearly any deficiencies in the CSs and CMs necessary for learning. Schemas of these kinds reflect the whole great system of contents and links (propositions). According to one work (Novak & Gowin, 1984), we can use the word "monstrous" here. The inclusion of excessive detail can prevent the students from understanding and mastering the material. The main cause of this is found in the basic idea of semantic representation of concepts and propositions. Generally speaking, science is not a system of words and proposition. It is a system of ideas and laws. One of the main aims of education is to help students to understand and to perceive the **sense** of these ideas and laws. However, the very detailed structure of words and propositions is not always the best tool to reach this aim. Otherwise, our traditional science education based on oral and written words would be much more successful. So CSs and CMs based on detailed semantic techniques can not be the only possible schematic tool for good learning for students. The other types of schemas - schemas of educational contents - can solve some of the aforementioned problems.

Schemas of Educational Contents (SECS)

SECs used in science education reflect the concrete content of the curriculum. They include supportive schemas, schema-summaries, various structural and logical schemas, etc. (Orlik, 1988). It is appropriate to start discussing them by considering the schemas of supporting signals (SSs) applied by V.Shatalov (Ukraine) and his followers(Shatalov, 1979; 1980). These kinds of SECs are used in teaching some subjects both at the secondary level and in Universities. What are SSs? SSs are used to model abstract theoretical material, and as such, are similar to common visuals. SSs can contain signs defining new information, key words, simple sentences, etc. Besides these, teachers often include stimulating material here, since mnemonic methods contribute to better storage of this knowledge in long-term memory. So SSs are the specially encoded and arranged contents of the topics of the theme of the theoretical course. (See Fig. 2)

It should be pointed out that such instructional means as SSs have been known and used by teachers for quite a long time. For example, K.Paustovsky, well known Russian writer, in his memoirs (Paustovsky, 1962) wrote that a teacher of geography in a school in Kiev in the 1890's used visuals for schematic representation of information (Fig. 2a)

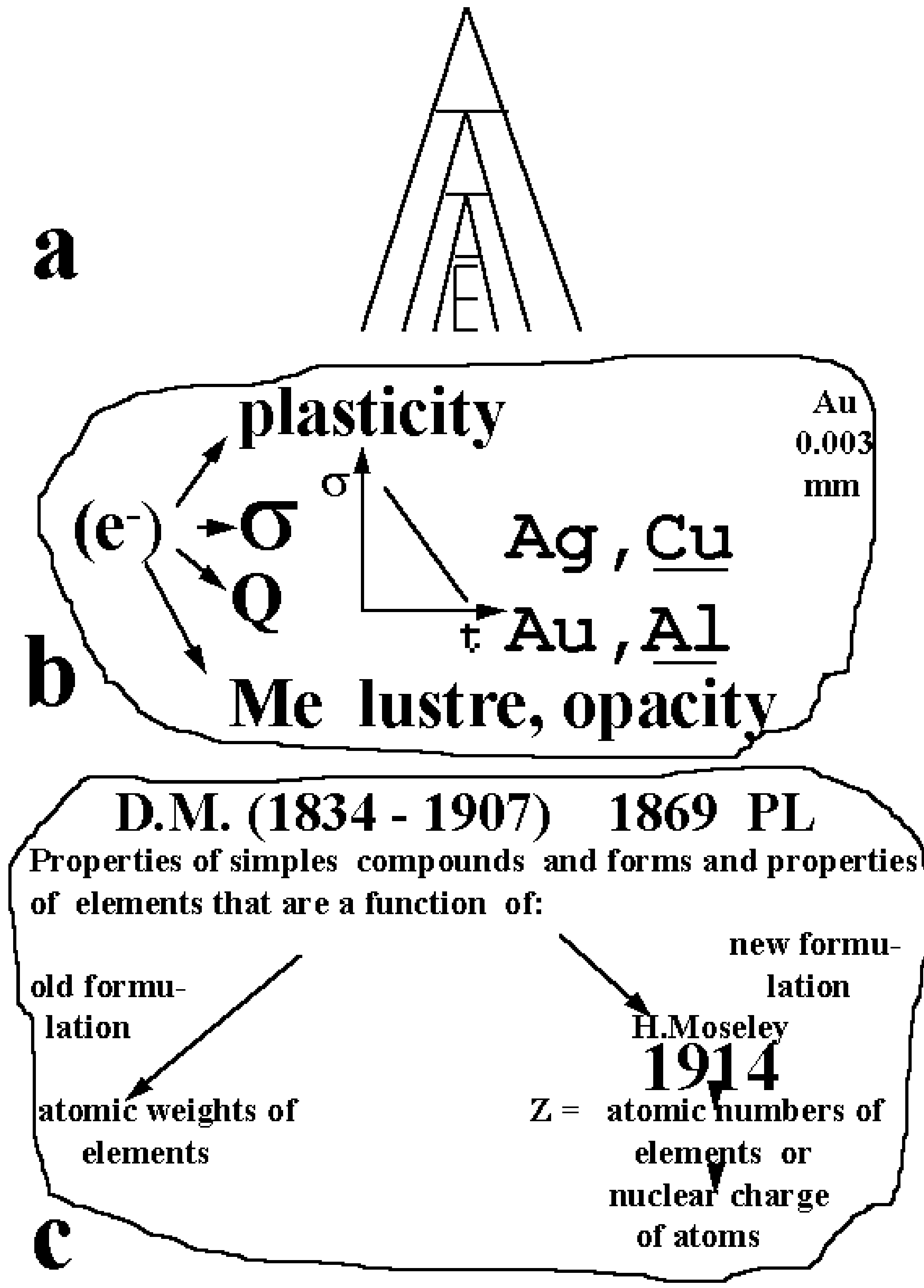


Fig. 2. Examples of SSs from different theoretical courses:

a. SS from Geography ("In Asia is Arabia, In Arabia is Aden, In Aden are Englishmen").

b. the block of information from SEC with SSs "Physical properties of metals" from General Chemistry. (Description of SS: Me - metal).

c. The block of information from SEC with SSs "Periodic Law" from Inorganic Chemistry. (Description of SS's: D.M. - Dmitri Mendeleev, PL - Periodic Law).

In Fig. 2b and 2c are presented two parts of SECs with SSs from our Inorganic Chemistry course. V.Shatalov and his followers are credited for creating a whole system of such instructional tools. According to (Sikora, 1989) the introduction of such innovations (based on the theory of Galperin P. about the formation of an oriented basis of activity) into teaching practice is revolutionary, not only for pedagogics and psychology but for other sciences as well. This statement can be viewed with some scepticism, but such instructional schematic tools as SSs are doubtless worthy of close attention both on the part of psychologists and teachers.

In our opinion it is reasonable to show the sense of SS using such concepts as image and symbol. It is known (Jukovsky, Pivovarov & Rakhmatullin, 1988) that a visual image is not a copy of an object but the result of cognition, it carries with it the sense created from previous learning. It is a mixture of logical reasoning interacting with the area of human perception. It is important for a person handling visuals (in our opinion this is also true for SSs), that s/he be able to see and to comprehend more than the actual content. If s/he associates these visuals with his/her previous experience in carrying out efficient mental operations the total volume of knowledge can exceed the amount of information accumulated in previous experience. Thus the perception of a visual, may make human activity more creative. Interconnections between emotional and rational aspects being common to any cognitive process, the content of integrated images formed as a result of interrelation and penetration of sensitive perceptive notions and concepts corresponding to them can be represented in the form of graphs, schemes, etc. (Serebriany, 1988).

In our opinion SSs can be included in this list. A symbol as a visual representation can reflect a law because symbols convey the essence of abstract ideas and lend them a perceptible and visual form (Serebriany, 1988). While perceiving any visual image (SSs in our case), students develop both general and conceptual thinking in close relationship. One of the major functions of SSs in SECs is that they facilitate the comprehension of information and identification of key points, establish connections between new concepts, and associate new knowledge with what has already been studied.

This is one of the prerequisites for forming a creative and efficient mode of thinking, since new knowledge is always based on previous experience (Novak & Gowin, 1984).

In SECs with SSs the didactic material is presented in a restructured form thanks to its unification into large blocks of information. These SECs in fact are special compact carriers of large portions of information. (It is only compact if it is meaningful to the learner) In Fig. 3 is presented the SEC with blocks of teaching information for an Inorganic Chemistry course. Colours in

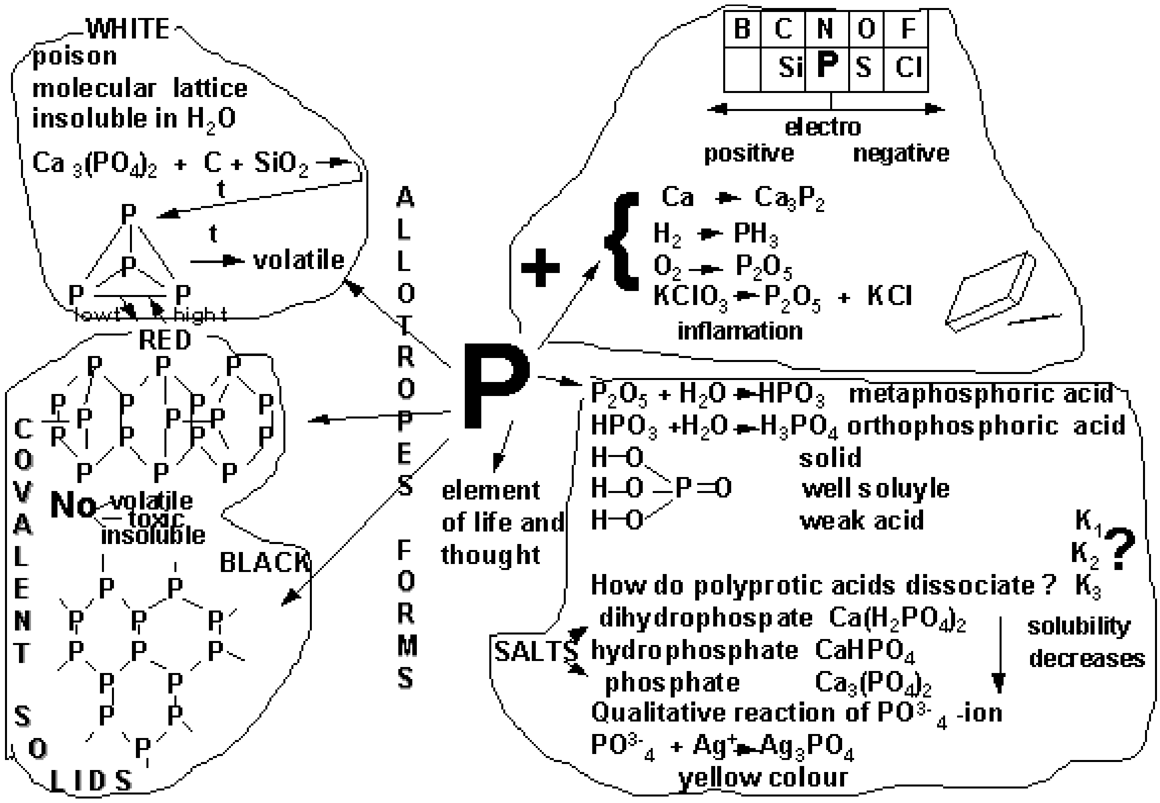


Fig. 3. SEC "Phosphorus" from Inorganic Chemistry.

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this SEC could play the systematic role as tools to attract the attention of students to corresponding subsystems of teaching information (red = redox properties, blue acid-base properties, yellow = methods to obtain compounds , green = active didactic questions and tasks).

The application of SSs to the framework of SECs has not been sufficiently studied. This question is important because teachers should include SECs containing many SSs during a lesson; without this preliminary stage, students can have difficulties trying to work with them individually. That is why, while using SSs in SECS, intended for ISW, it is necessary to apply a limited number of SSs and to try to construct them using notational conventions, signs and symbols familiar to the majority of students. (Such as?) These SECs are evidently easier to design for those disciplines in which schematic form of content representation is natural. In Chemistry, equations of chemical reactions are known to be basic, and they are traditionally presented in a schematic form.

Algorithmic Schemas (AS)

One more kind of schema can be identified that has an algorithmic character - ASs. ASs can be effectively used to help students solve different numerical and qualitative problems, in completing exercises and in the experimental laboratory work (Greeno, 1976; Waddling, 1988; Ashmore & Frazer, 1979). ASs help students to get good skills in calculating problems and permitting mastery of experimental methods in the laboratory. For students ASs facilitate their learning how to perform chemical experiments and study the ways to process experimental data and related calculations. Fig. 4 represents one of the ASs used in solving problems in General Chemistry.

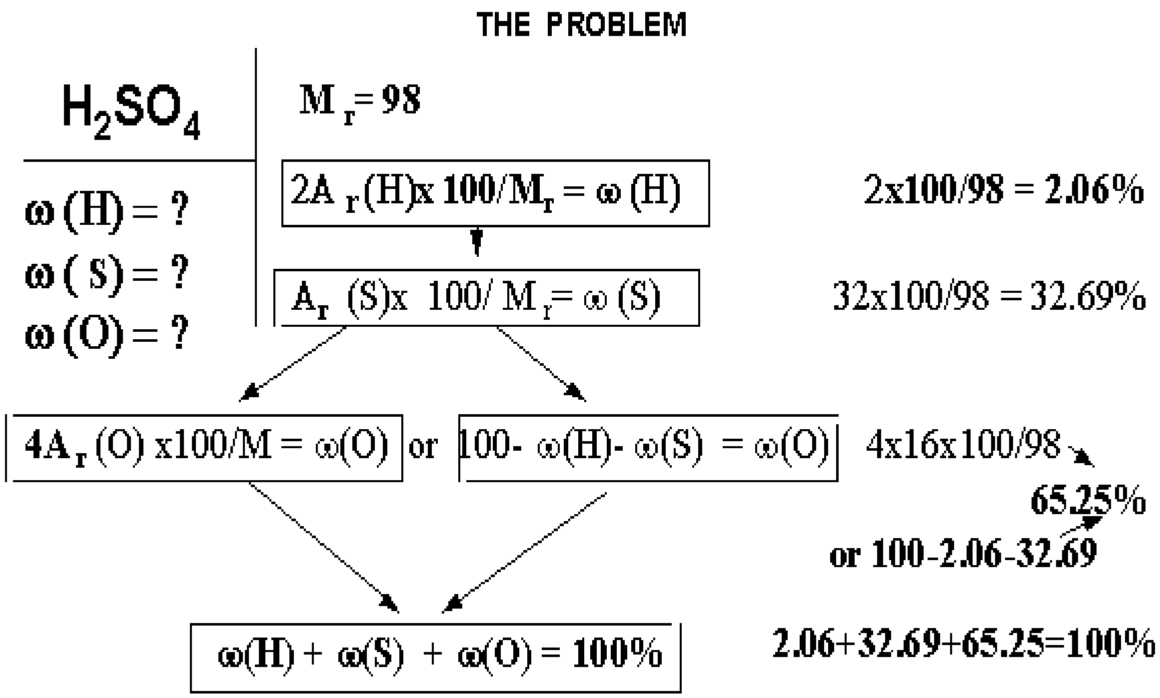

Figure 4. AS for solving numerical problems in General Chemistry

What benefit can be achieved by using CSs, SECs and ASs in classes and ISW?

Using different kinds of schemas and algorithms for presenting various types of educational material is one way to make the learning of science courses more enjoyable and effective for students. Essentially, the schemas can free students from summarising the lectures. While listening to a lecture the students consult schemas which facilitate their comprehension of interrelations and links between concepts. As CSs and SECs reflect the logical sequence of questions to each topic and the more important information in the subject, they facilitate proper allocation of material to be studied individually. It is easier to work with a textbook while referring to schematic material organisers.

Some teachers have noted that the use of the schemes allows them to achieve a considerable time economy 20-25% when teaching the subjects of the natural-scientific cycle. This allows the lecturer to give more than a single explanation of the educational material in some cases, and also enables the student to learn better (Orlik, 1988).

The time economy, mentioned above, presents a real way which makes it possible to reduce the amount of time needed for lectures, by allowing for a corresponding time increase for ISW in the absence of a teacher. Control and self-control of knowledge and skills are carried out more effectively with the schemas (Orlik, 1988).

It's possible to apply such schemas in ISW, which can combine with other ways of active learning, for example, students can supplement them during the learning process. It is also possible to apply different methodology. For example, students can complement the SECs with blocks without the didactic information. This learning activity allows them not only to develop in remembering the material but to master creative skills and abilities. In the ISW they can design their own SECs and CSs too.

The schemas are very useful for ISW in the process of reviewing and in the preparation for examinations. The process of students' preparation for examinations includes work with the complete set of CSs and SECS, which are spread on a surface (e.g. on the table surface) for the best way to survey sections of topic material and for the best mastering of their interrelationships see(Orlik, 1988).

Structuring the theoretical material by means of described schemas is also very useful for the improvement of traditional Chemistry textbooks. Using CSs and SECs in the structure of textbooks can correct some of their defects and allow for a better learning of the main chemical material (Orlik, 1988, Orlik & Mozolevskaya, 1990). Schemas can also be the special means for creation of new types of computer educational software for Chemistry teaching (Orlik, 1993, Li & Merrill, 1991).

Conclusions

The application of the schemas approach in chemical education demonstrates that it is an effective means for the representation of didactic information in various types of teaching and learning activity. Schematic representation of information is one of the tools which can contribute to restructuring of instruction toward the transition to a more creative style of teaching science subjects. Further study of schema applications in classes and in textbooks will lead to the design of more efficient teaching methods and their use will aid the purpose of improving and developing educational standards.

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